U.S. Department of Transportation
Federal Aviation Administration

Aeromedical Research Resume
Research Project Description Subtask for FY99

1. Title:	2. Sponsoring Organization/Focal Point (FP)	3. Originator Name, Organization, Phone:
Design, Testing, and Evaluation of new ATS Technologies and System Concepts	ARX-1; J. Staples AAM-1; J. Jordan, M.D. AAR-100; L. Cole (FP)	Carol Manning, Ph.D. Henry Mertens, Ph.D. Roni Prinzo, Ph.D. Scott Mills, Ph.D. Rich Thompson, Ph.D. AAM-510 (405) 954-4846
		4. Origination Date: October 1998
5. Parent RPD Number: 586	6. Subtask Number: AM-B-99-HRR-516	7. Completion Date: September 2000
8. Parent MNS: ATS Human Factors	9. RPD Manager Name, Organization, Phone: David J. Schroeder, Ph.D. AAM-500, FAA Civil Aeromedical Institute (405) 954-6825.	

10. Research Objective(s):

The purpose of this research program is to ensure that ATS systems are designed to accommodate the user and to conduct real-time simulations and longitudinal assessments to determine whether the human has been sufficiently accommodated. The program encompasses three areas of research: 1) Conduct simulation studies to assess and compare new capabilities being considered for inclusion in future ATS systems, 2) Develop measurement tools to assess system effectiveness, and 3) Use measurement tools to evaluate the effectiveness of both ATS systems and the processes used to implement them.

This project also supports the development and demonstration of laboratory facilities that will be used to test design and development issues associated with future ATC systems, such as DSR, STARS, Pilot/Controller Data Link Communications (PCDLC), use of color, and Free Flight.

11. Technical Summary:

This research will support the development of future ATS systems by providing information about the effects of proposed system capabilities on the performance, taskload, and cognitive processing of individual air traffic controllers and also effects on system performance measures. The research will also evaluate newly-introduced ATS systems and the methods used to introduce them to the workforce, assessing effects on productivity, workload, and organizational climate. In order to conduct simulation testing and system evaluations, it is first necessary to develop measures that accurately describe individual and system performance.

A set of studies is proposed that will focus on simulation of future system concepts, development of measures of system effectiveness, and using the measures developed to evaluate the effectiveness of new systems and the process of implementing those systems. Projects addressing flight strip reduction, use of color in STARS, data link, graphical display of decision support information and information about factors related to ATC complexity, development of measures of controller taskload, performance, decision making, and situation awareness will be conducted, beginning in FY-99, with some being completed in FY-00. Other studies to measure baseline levels of taskload and performance will also be conducted.

12. Resource Requirements: ***FY-99*** ***FY-00***

FAA Staff Years:	14.0	14.0

13. Description of Work:

(1) Brief Background Introduction of new technologies may result in unintended consequences for the ATS system. Problems have already occurred with automation of the flight deck (Billings, 1997). For example, pilots have had problems determing how to interpret information present on displays, and have had difficulties maneuvering through systems of menus used to obtain information. Problems have also occurred because automation does not display all relevant information to the pilot and because the pilot does not understand how the automation works and so is surprised by actions taken by the automation.

Automation of the ATC system has not yet been introduced in the United States and so controllers have not yet encountered automation problems of the sort that have occurred in flight deck automation. Knowledge of problems with flight deck automation may reduce the incidence of similar problems with ATC systems, but the domains are not identical, and so some unexpected problems are likely to result. A number of concepts about new ATS systems have been introduced (for example, data link, free flight, conflict probe, etc.). These system concepts should be evaluated through the use of simulation testing before design decisions are finalized. Simulation testing is also useful for comparing alternate versions of displays to determine if any have negative effects on controller workload and performance. It is important in these simulation tests to assess not only easily quantifiable measures such as numbers of aircraft, but also to assess the effects that new system concepts may have on controller understanding of the situation and other kinds of cognitive processing that occur.

Simulation testing of several new system concepts has been conducted in the Human Resources Research Division for several years. A series of studies compared current use of flight progress strips with a) two electronic alternatives, 2) no flight strips, and 3) a smaller flight strip. A study currently underway is comparing current use of flight strips with a procedure that allows reduced marking and posting of flight strips. This research has been conducted at the FAA Academy Radar Training Facility (RTF) laboratory and in DYSIM labs at several en route centers. A second project resulted in completion of two studies examining the effects of Controller/Pilot Data Link Communications. These studies used DFW TRACON controllers as participants. A third project will result in the development of guidelines for use of color in new system designs. These guidelines will be applied in studies examining the use of color coding in situation displays for the Standard Terminal Replacement System (STARS). A fourth project is identifying ways to graphically represent information determined to be related to complexity of air traffic situations and will test those concepts using simulation.

One type of research that will be conducted in this program is simulation testing of new ATS system concepts. A second part of this research program involves developing measures that can be used to compare alternative versions of proposed systems as well as evaluate the effectiveness of new systems when they are introduced in the field. A number of measures have been utilized in simulation studies conducted for previous projects. These include measures of cognitive processing, performance, workload, efficiency and situation awareness. Some of these measures are subjective, requiring subject matter experts to observe study participants run simulated scenarios and evaluate controller performance based on their observations. Other measures are based on the participants' opinions of what was occurring during different parts of the scenario. A few measures are taken from actions made by the participant at the time the scenario is running. One project that will be conducted as part of this research program involves the development and validation of measures of air traffic controller decision making. These measures, when completed, will be applied to the assessment of new ATS system concepts.

A set of measures based on objective data is currently under development. These measures, called Performance and Objective Workload Evaluation Research (POWER) are computed from available System Analysis Recording (SAR) data. The output of POWER is a set of numerical measures that may be related to controller taskload as well as controller and system performance. An engineering validation and assessment of the psychometric properties of the measures will assess their utility for measuring ATCS taskload and performance. When the properties and limitations of the measures are understood, they will be applied to the calculation of baseline measures for the current NAS. Another set of measures Is being developed to assess the effects of technology implementation and change on organizational perceptions and performance.

The third type of research to be conducted as part of this program involves utilizing the measures of system and individual performance and effectiveness developed earlier to evaluate new ATS systems such as the Display System Replacement (DSR). Besides evaluating the human machine interactions associated with the use of the equipment installed, another type of evaluation examining the organizational effects of new systems is planned. Such evaluations, which begin before new equipment is installed, can identify potential problems with workforce acceptance of new systems before implementation occurs and identify problems with system implementation and transition training so they can be avoided in the future. It is expected that the methodologies developed during this project will be used to evaluate effectiveness of DSR implementation and the associated transition training. Other, more traditional organizational assessments will be conducted to generate a longitudinal data base for evaluating efforts at enhancing job satisfaction and the overall organizational climate for ATS personnel. Outcomes will also identify progress toward achieving Model Work environment goals.

(2) Statement of Work Subtasks:

Hypothesis: Potential problems associated with the effects of proposed ATS system changes on individual controller and system performance can be identified through real-time simulation.

Hypothesis: Measures of En Route controller performance, taskload, sector complexity, and decision making can be developed and applied to the evaluation of future ATC systems designs and concepts.

Hypothesis: Measures of technology changes and organizational effectiveness will provide a sufficiently sensitive technique for identifying potential problems associated with proposed ATC system changes.

The following subtasks will be initiated in FY-99:

- **Reduction of paper flight progress strips**. If paper flight progress strips are removed, how might the information currently obtained from them be otherwise displayed? Alternative versions of electronic displays for flight progress data will be compared using the ATCARS simulator. Procedural changes related to the use of flight progress strips will also be tested.

- **Color coding in STARS and other future ATS displays**. While color coding may enhance performance in some applications, improper use of color coding can impair performance. Certain applications of color to the STARS environment will be tested, including displaying “owned” and “non-owned” aircraft using different colors, using color to highlight aircraft involved in alerts, and using color to make the display more legible when data blocks overlap.

- **Human factors of controller/pilot data link communications.** Studies will be initiated that assess the effects of using data link on controller performance.

- **Controller decision making.** Controller decision making plays a critical role in ensuring aircraft separation in the current system. Baseline measures of decision making are needed to develop improved decision aids and to assess the effects of automated system concepts. Measures of controller decision making will be developed and evaluated. Alternative methods for displaying decision support information will be assessed.

- **Identification and display of ATC complexity factors.** This collaborative study with the WJH FAA Technical Center Human Factors Laboratory is designed to develop graphic displays of factors related to ATC complexity. Simulation studies with ATCSs will be conducted to assess the effectiveness of proposed display designs.

- **POWER taskload and performance baseline assessments.** Objective measures of controller and system performance are needed to assess the effects of procedural and technological changes. A set of numerical measures based on available SAR data will be developed to assess controller taskload as well as controller and system performance. An engineering validation and analysis of the psychometric properties of the measures will assess their utility for measuring taskload and

performance. The resulting measures will be used to compute baseline levels of taskload and performance at en route facilities. Data for facilities receiving DSR in this time frame will be collected and analyzed to compare taskload and performance before and after DSR implementation. Multiple assessments following DSR implementation will be used to assess short- and long-term effects.

- **Effects of DSR implementation and transition training on organizational climate**. Lifecycle approaches to assessing new technologies and procedures include assessments of training provided and the methods used to implement new systems. A systematic approach to understanding the corporate culture prior to and shortly after implementation of the new technology provides managers with an effective data base to support decision making and facilitate planning for implementation at other sites. This project will focus on acquiring data from personnel at selected facilities before and after major technological changes are made, including DSR. Longitudinal assessments of the ATS organizational culture will support senior managers in determining progress toward development of a model work environment and improving the overall quality of employees' work life.

14. Intended End Products/Deliverables

Products:

Information about the effects of proposed procedural and equipment changes (for example, reduced strip marking and posting, data link, use of color for ATS displays, etc.) that can contribute to management decision making:

- Guidelines for use of color in new system designs
- Identification of potential human factors problems with system concepts before system design is finalized
- Identification of potential problems with workforce acceptance of new systems before implementation occurs
- Development of methods that can be used to assess system effectiveness
- Guidelines for enhancing employee acceptance of new systems
- Identification of problems that occurred with system implementation and transition training so they can be avoided in the future

15. Schedules/Milestones

Reduction of paper flight progress strips.	FY99
Conduct study comparing effects of using alternative electronic displays of flight progress data.	Q4
	FY00
Conduct study evaluating alternative procedures for using flight strips.	Q3
Complete report and provide briefing of results.	Q4
Color coding in STARS and other future ATS displays.	FY99
Complete study assessing the effectiveness of displaying "owned" and "non-owned" aircraft using different colors	Q3
	FY00
Complete study using color to highlight aircraft involved in alerts	Q3
Human factors of controller/pilot data link communications.	FY00
Conduct study to assess effects of using Data Link on En Route controllers.	Q2
	FY00
Complete report describing results.	Q3
Controller decision making.	FY99
Complete initial assessment of controller decision making measures	Q4

	FY00
Develop display methods for ATC decision support systems.	Q2
Complete report describing study results.	Q4
Identification and display of ATC complexity factors.	FY99
Develop graphic displays of factors related to ATC complexity.	Q1
Conduct simulation studies to assess effectiveness of proposed display designs.	Q4
	FY00
Complete report describing results of study.	Q2
POWER taskload and performance baseline assessments.	FY99
Complete psychometric evaluation of POWER measures.	Q2
	FY00
Compute baseline levels of taskload and performance at selected en route facilities based on SAR data.	Q1
Collect and analyze early post-DSR implementation SAR data to compare taskload and performance before and after DSR.	Q4
Effects of DSR implementation and transition training on organizational climate.	FY99 Q3
Collect data regarding employee perceptions of technology change.	
	FY00
Collect data regarding employee perceptions of the effectiveness of DSR implementation and transition training.	Q4

16. Procurement Strategy /Acquisition Approach/Technology Transfer:

Research on this project will be conducted by in-house staff with varying backgrounds in human factors, experimental design, vision, software development, decision theory, organizational development, and industrial psychology. Several contracts and grants/cooperative agreements with highly qualified researchers in organizations such as the FAA Technical Center, the University of Oklahoma Psychology and Computer Science Departments, the Kansas State University Psychology Department, and other academic institutions will be used to expand our ability to address certain issues. Technology transfer will be available through the scientific media and existing FAA structures. It is anticipated that the acquisition of specialized hardware/software will be required to enhance and upgrade our capability to develop ATC simulations for assessing the effects of color-coding and other future display characteristics and prototypes on controller performance ($180,000).

17. Justification/History:

The research program described here relates to several research categories included in the ATS Human Factors Research Project Description for FY-00. These are ATC Information Display and Interface Design, Decision Support Systems and Collaborative Decision Making, Airspace Design and Procedures Human Factors, and General Human Factors Research. The program also relates to other FAA planning documents, such as the FAA Strategic Plan (under the Human Factors goals for safety and system capacity), the NAS ATM R&D Advisory Committee, which recommended looking at the effects of Free flight on controller performance. The program also supports the ATS Operations Concept for 2005 NAS, as well as goals in the En route/Oceanic Mission Needs Statement. This research also supports the enabling activities described in 1997-99 ATS Business Plan. These research program activities are designed to respond to requirements and information needs identified in the NAS Architecture Version

3.0. This includes: 6.3 Communications – Human Factors; 8.3 NAS Information Services for Collaboration and Information Sharing – Human Factors; 9.3 Traffic Flow Management – Human Factors; 10.3 En Route – Human Factors; 12.3 – Terminal – Human Factors; and various 21.0 NAS-Wide Topics (21.2 Human Factors Activities – life cycle costs, benefits, and tradeoffs, human performance metrics and baselines, consistent computer-human interface prototypes, human-in-the-loop simulations, and task analysis and workload measurement).

***18. Issues**:*

Conducting this research will require air traffic control specialists to serve as participants in research studies. Simulation laboratories at CAMI, the FAA Technical Center's Human Factors Laboratory, the FAA Academy's Radar Training Facility (RTF) simulator, or en route DYSIM facilities will be used. A description of the research protocol and subject consent form will be submitted to the CAMI Institutional Review board for approval. When appropriate, coordination for access to controllers to participate in research studies will occur with ARX-100, Labor Relations, and NATCA. It is necessary to obtain accurate and up-to-date system/service descriptions and obtain timely information about system changes. It will also be necessary to coordinate obtaining SAR data from facilities and coordinate permission to travel to field facilities to collect other relevant data required to evaluate new systems. Access to this type of information will be arranged through ARX-100.

19. Transition Strategy:

This project will produce methods for comparing proposed future ATS system concepts. Simulation studies will be conducted to compare and assess these system concepts. Other studies will assess effects on performance, productivity, and organizational climate resulting from the introduction of new air traffic control systems. Based on laboratory studies of alternative design configurations, recommendations will be made for future versions of automation that are likely to increase productivity and reduce errors. Results of research conducted as part of this project will be in the form of recommendations regarding methods for displaying information, revising procedures, or implementing new systems that should reduce the likelihood of negative consequences associated with technology change. The recommendations will be documented in technical reports, then will be briefed to FAA ATC managers and members of controller teams. Discussions will be held to determine how the results might be implemented.

20. Impact of Funding Deferral:

Deferral of funding for simulation studies will result in failure to identify human factors problems associated with future ATS system concepts in a timely manner. Such a lack of identification could lead to committing to a flawed system design that would have to be changed late in the development process, resulting in delays and excessive costs. Deferral of funding for development of individual and system measures of performance, taskload, decision making, etc., will result in not being able to evaluate the effectiveness of new systems after they are implemented. Not conducting evaluations of the effectiveness of new systems will result in failing to incorporate lessons learned into plans for implementation and transition training for future systems and may lead to the same mistakes being made again.

21. R&D Teaming Arrangements:

This program of research is related to other research being conducted at CAMI. For example, knowledge gained from the development of SATORI contributed to the methods that the ATCARS simulator uses to obtain, display, and record simulation data. Knowledge gained from these projects will contribute to a redesign of the Operational Error/Deviation reporting form. Measures developed as part of this research program will be used to evaluate the effects of environmental factors on controller performance. The development of the performance measures used in these studies will be linked to the development of criterion performance measures required for validation of new selection procedures.

FAA Principal Investigators involved in this research program also collaborate on external projects. For Example, AAM-510 researchers are collaborating with FAATC, NASA, and MITRE researchers on a project to develop dynamic density measures for ATM systems. A collaborative project with members of the Human Factors Laboratory at the FAATC has been underway for over a year. FAA Principal

Investigators also participate on aviation committees, for example, the SAE G-10 Free Flight and Data Link subcommittees.

22. Special Facility Requirements:

Some studies will be conducted in laboratory facilities available at CAMI. These include the Air Traffic Control Advanced Research Simulator (ATCARS), which simulates ATS future system concepts; the Color Vision laboratory, which includes equipment for measuring color vision deficiencies as well as operational ATS equipment requiring the use of color; the TRACON/Data Link laboratory, which allows simulation of the TRACON environment and also allows assessment of data link issues; the Systematic Air Traffic Operations Research Initiative (SATORI), which allows re-creation of air traffic situations based on an integration of files produced by DART and NTAP with digitized pilot/ controller communications. Some studies have also been conducted at the FAA Academy's Radar Training Facility (RTF). To generalize the results of any of these studies to the operational environment, it will be necessary to replicate or expand some of the experiments using operationally current air traffic controllers working with DYSIM equipment located at en route centers.

23. Approvals (Signature Authority):	***Project Revalidation***	***Performing Organization***
_____ Jon L. Jordan, M.D. Federal Air Surgeon (AAM-1)	_____ *Date*	William E. Collins, Ph.D. Director, FAA Civil Aeromedical Institute, AAM-3
_____ John Staples Director, Plans and Performance Program (ARX-1)	_____ *Date*	_____ *Date*